A Research Proposal

On

"Measurement and correlation of heat transfer coefficient (h) of HCFC-22 alternatives"

BY

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UNDER THE GUIDANCE OF

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1. Introduction

Refrigeration technology plays an important role in present society as it helps to improve the comfort of human beings and preservation of food. It provides not only comfortable and healthy living environments but also improves the working efficiency. These technological advances that contribute to human comfort, they are also threatening the environment through ozone layer depletion and global warming.

Ozone layer depletion (ODP) and global warming are two major environmental concerns with serious implications. Ozone layer efficiently screens all the harmful ultraviolet rays of the sun by absorbing most of the dangerous ultraviolet B (UV-B) radiation. ODP is defined for any given substance as the ratio between the ozone consumption per unit mass of the refrigerant released in the atmosphere and that consumed by R11, accounts for this effect.

The second major environmental issue is Global Warming potential (GWP), which is due to the absorption of infrared emissions from the earth, causing an increase in global earth surface temperature (8).

Two major environmental problems have resulted in a series of international treaties demanding a gradual phase out of halogenated fluids. As per the Montreal Protocol 1989, the most environmentally harmful refrigerants, such as CFCs have been banned since 1995. HCFC will be phased out by developed countries in 2020 and for developing countries in 2030. R22 is accepted as the most suitable refrigerant but it will be phased out as per the schedule (1-6).

R22 has been widely used for many decades as a primary working fluid in various air-conditioning systems. Unfortunately, it was considered as a harmful working fluid to the environment. As a result, many environmental issues related to alternative refrigerants and energy efficiency were reported in the literature. In addition, experimental and theoretical investigations were carried out to find R22 alternatives in domestic, commercial and industrial air-conditioning systems. Nowadays, several substitute mixtures are already in the market (R410A, R407C, R404A, R290 and others) (10). Theoretical and experimental investigations (7-9) were carried out to assess azeotropic and zeotropic mixtures as R22 substitutes in vapor compression refrigeration systems (VCRSs) (8).
A list of the most potential alternative is given in Table 1. It also includes safety group as per ASHRAE standard 34. As per the literature survey, R407C is found the best candidate as a drop in substitute for R22 (9).

Table 1

Properties of Few Alternatives to R22

S.No	Refrigerant	Molecular weight (kg/kmol)	NBP (^{0}C)	T_{CR}(^{0}C)	P_{CR}(MPa)	ODP	GWP (100 years)	Safety Group
1	R22	86.47	-40.8	96.20	4.99	0.055	1700	A1
2	R134a	102.03	-26.1	101.1	4.06	0	1300	A1
3	R290	44.10	-42.1	96.8	4.25	0	11	A3
4	R407C	86.2	-43.6	86.1	4.62	0	1530	A1/A1
5	R410A	72.56	-50.5	72.5	4.96	0	1730	A1/A1

2. Literature Review

Evaporator is a significant and essential heat exchanger in refrigeration and air conditioning systems. A well designed evaporator improves the performance of the whole refrigeration system. Thus, an efficient evaporator should be designed to enhance the heat transfer characteristics and cycle efficiency of the system. Different methods have been used by investigators to increase the heat transfer rates in evaporators (11).

The experimental results indicate that the heat transfer coefficients increase with mass velocity and heat flux. Kundu et.al. (11) had measured flow boiling heat transfer coefficients and pressure drops of R134a and R407C inside a smooth horizontal tube. The heat transfer coefficients of pure fluid R134a are always higher than that of refrigerant blend R407C for same operating conditions. The frictional pressure drop gradients of R134a are higher than R407C for all mass velocities; where the pressure drops of both refrigerants depends merely negligible on heat flux variations.

The reduction in evaporation pressure drop decreases the energy consumption up to 6.6%, and the system that has less pressure drop requires a lower specific heat transfer surface area up to 8% with the same energy consumption. Smooth horizontal tubes with small diameter utilized in evaporator facilitate compact arrangements, large heat transfer coefficient with less frictional pressure drop (11).

Lee et al. (12) did experimental study of a fin and tube condenser using two different configurations of condenser paths (U and Z type) and two kinds of refrigerants (R22 and R-407c) as working fluids to evaluate the heat transfer capacity of the condenser and to validate the simulation results . An uncertainty study was also performed. Different condenser capacities were obtained from both the experimental and numerical results, depending on the paths and refrigerants used. Among the alternatives for R-22, one of the more promising refrigerants is the ternary mixture R-407c, composed of HFC-32/125/134a, 23/25/52 wt.%.

When the compensation method for the in-tube heat transfer coefficients of ternary refrigerant mixture was used, all of the numerical results using R-407C underestimated condenser performance compared to the experimental results in the Z and U-type paths. Therefore, more accurate modeling of the in-tube heat transfer coefficient for the ternary refrigerant mixture is needed in future (12).

Mancin et al. (13) had done the experiments on partial condensation of superheated vapours of R407C and R410A inside two Brazed Plate Heat Exchanger prototypes with different geometrical characteristics, plate designs and aspect ratios. They showed that the condensation heat transfer coefficient increases with vapour quality and decreases with temperature difference. Mancin et al. proposed a new model to simulate the condensation process through the Brazed Plate Heat Exchanger.

At constant mass velocity, the condensation heat transfer coefficient increases with outlet vapour quality. At the same outlet vapour quality, for both refrigerants, the heat transfer coefficient is almost constant when varying the mass velocity from 15 to 20 kg m^{-2} s^{-1} (13).

Kundu et al. (14) had done the experimental investigations with refrigerant R407C during flow boiling inside a smooth tube of inside diameter 7.0 mm at different tube inclinations. In this experiment, the effect of mass velocity, heat flux and tube inclinations on evaporative heat transfer coefficient had been investigated. An empirical correlation was developed to predict the heat transfer coefficient of R407C during flow boiling inside an inclined plain tube. Five different tube inclination angles from 0^0 to 90^0 were studied. The temperature range was 6^0C to 9^0C.

Refrigerant mass velocities from 100 to 300 kg m^{-2} s^{-1} and heat fluxes between 3 and 6 kW m^{-2}. The average quality of boiling refrigerant was between 0.1 and 0.9. The influences of the above parameters on the boiling heat transfer coefficient with tube inclinations are presented (14).

Mancin et al. (15) investigated the condensation heat transfer of two refrigerants mixtures, R407C and R410A, in a brazed plate heat exchanger to calculate the heat transfer coefficient. They showed that the condensation heat transfer coefficient increases with vapour quality and decreases with saturation to wall temperature difference. A new computation procedure, to estimate the condensation heat transfer coefficient inside commercial brazed plate heat exchanger has been compared against the present experimental results showing good predictions (15).

The condensation heat transfer coefficients of R407C and R410A have been measured at constant inlet saturation pressure of 1.6 MPa and 2.2 MPa, respectively. For both refrigerants, the superheating at the inlet of the heat exchanger was around 15 K; the mass flux has been varied from 15 to 40 kg m^{-2} s^{-1} whereas the outlet vapour quality has been changed between 0.07 and 0.58 in order to investigate the effect of vapour quality (15).

Kundu et al. (16) experimentally investigated on two phase flow evaporative heat transfer of refrigerants R134a and R407C in a smooth copper tube inclined at five different angles between 0^0 and 90^0 was conducted. The experimental data were obtained over a mass velocity range of 100–300 kg/m2 s, heat flux range of 3–10 kW/m2, inlet temperature range of 5–9 ^{0}C and vapor quality varied from 0.1 to 0.9. The test section was 1.2 m long, smooth copper tube with inner diameter of 7.0 mm and outside diameter of 9.52 mm. It means 1.26 mm thick tube.

3. Research Gap

The heat transfer coefficient of HCFC-22 alternatives are not available in the flow of the refrigerant through evaporator, condenser and pipe lines in combination of a refrigeration system. The requirement of this is in the variable flow refrigerant system, where the refrigerant travels very long distance. Parametric conditions of heat transfer and pressure drop in variable mass flow rate with different tube diameters are not available. These parameters decide the outdoor unit power requirement and indoor unit cooling conditions.

4. Research objectives

The main objective of all the research works in this field is to obtain the highest heat transfer rate with the least pressure drop.
The objectives of the present study are

To develop an accurate variable mass flow rate requirement and pressure drop database for important new refrigerants and to provide data to the refrigeration industry for the design of highly efficient evaporators (or condensers).

5. Conclusion

On the basis of literature it has been found that heat transfer coefficient for (flow boiling and condensation) different alternative refrigerants can be found out experimentally under different operating conditions. E.g. changing the length or tube diameter will affect the heat transfer coefficient also under different temperature range and tube inclinations.
It is decided that an experimental facility will be developed in the mechanical engineering department to conduct the experiments on heat transfer and pressure drop.

6. Activity plan

S. No.	Activity	Time (Months)
1	Design of the experimental test rig	1
2	Fabrication and assembly of test rig	3
3	Experimental work	2
4	Results and discussion	2
5	Thesis writing	3

7. References

1. B.O. Bolaji, Z.Huan, "Ozone depletion and global warming: Case for the use of natural refrigerant – a review". Renewable and Sustainable Energy Reviews 18 (2013) 49–54
2. James M. Calm, "The next generation of refrigerants – Historical review, considerations, and outlook". International Journal of Refrigeration 31 (2008) 1123 – 113 3
3. M. Mohanraj, S. Jayaraj, C. Muraleedharan, "Environment friendly alternatives to halogenated refrigerants—A review". International Journal of Greenhouse Gas Control 3 (2009) 108 – 119
4. D.J. Wuebbles, "The Role of Refrigerants in Climate Change". International Journal of Refrigeration 17(1994) 7-17
5. C.P. Arora, "Refrigeration and Air-conditioning" III Edition, Mc Graw Hill Education
6. Mark W. Spatz, Samuel F. Yana Motta, "An evaluation of options for replacing HCFC-22 in medium temperature refrigeration systems" International Journal of Refrigeration 27 (2004) 475–483
7. M.W. Spatz, J. Zheng, R22 Alternative refrigerants: performance in unitary equipment, ASHRAE Transaction 99 (1993) 779–785
8. C. Aprea and A. Greco, "An Experimental Evaluation of the Greenhouse Effect in R22 Substitution". Energy Conservation and Management 39 (1998) 877-887
9. S. Devotta, A.V. Waghmare, N.N. Sawant, B.M. Domkundwar, "Alternatives to HCFC-22 for air conditioners" Applied Thermal Engineering 21 (2001) 703- 715
10. M. Fatouh, Talaat, A. Ibrahim, A. Mostafa "Performance assessment of a direct expansion air conditioner working with R407C as an R22 alternative" Applied Thermal Engineering 30 (2010) 127–133
11. Arijit Kundu, Ravi Kumar, Akhilesh Gupta "Heat transfer characteristics and flow pattern during two-phase flow boiling of R134a and R407C in a horizontal smooth tube" Experimental Thermal and Fluid Science, 57 (2014) 344-352.
12. J.H. Lee, S.W. Bae, K.H. Bang, M.H. Kim "Experimental and numerical research on condenser performance for R-22 and R-407C refrigerants" International Journal of Refrigeration, 25 (2002) 372-382.

13. Simone Mancin, Davide Del Col, Luisa Rossetto "Condensation of superheated vapour of R410A and R407C inside plate heat exchangers: Experimental results and simulation procedure" International Journal of Refrigeration, 35 (2012) 2003-2013.
14. Arijit Kundu, Ravi Kumar, Akhilesh Gupta "Flow boiling heat transfer characteristics of R407C inside a smooth tube with different tube inclinations" International Journal of Refrigeration, 45 92014) 1-12 .
15. Simone Mancin, Davide Del Col, Luisa Rossetto "Partial condensation of R407C and R410A refrigerants inside a plate heat exchanger" Experimental Thermal and Fluid Science, 36 (2012) 149-157.
16. Arijit Kundu, Ravi Kumar, Akhilesh Gupta "Evaporative heat transfer of R134a and R407C inside a smooth tube with different inclinations" International Journal of Heat and Mass Transfer, 76 (2014) 523-533.